Comment on "Insulator-to-Metal Crossover in the Normal State of $La_{2-x}Sr_xCuO_4$ Near Optimum Doping"

In a recent letter Boebinger *et al.* [1] report the results of transport experiments in $La_{2-x}Sr_xCuO_4$ (LSCO), in the presence of high magnetic fields, allowing to access the normal phase underlying the superconducting region. They assess the presence of a metal-insulator transition in the underdoped region ending near optimal doping ($x = 0.17$) at $T = 0$. In this comment, we point out that their work not only shows the existance of a quantum critical point (QCP) *different from the* antiferromagnetic (AF) QCP, but also provides a clear evidence that the nature of this instability is related to charge-ordering. We also argue that a careful analysis of their data allows to locate the low-temperature metal-insulator transition, and therefore the QCP, at larger doping ($x \approx 0.2$) in closer agreement with the zero-temperature extrapolation of the pseudogap data reported in Ref. [2].

Several experimental findings give indirect support for the existence of a QCP at (or near) optimal doping: neutron scattering, optical spectroscopy, NMR, susceptibility, photoemission, specific heat, thermoelectric power, Hall coefficient, resistivity (see, e.g., the discussion in Ref. [3]). The resistivity measurements in Ref. [1] are the first direct evidence of a transition ending near optimal doping at $T = 0$. On the other hand, the origine of this transition to an insulating state is less easily established. A crucial hint, not considered by the authors, is provided by the observation that the resistivity curve for $x = 0.12$, i.e. near the "magic" doping 1/8, displays an insulating behavior at a much higher temperature than for values of x immediately nearby. This shows that commensurability plays a relevant role in establishing the insulating phase, thereby indicating that spatial order of the charge degrees of freedom should be involved also away from commensurability. This would also agree with the observation made in Ref. [1] that the system is rather clean ($k_F l \sim 13$) and the disorder cannot be the source of the transition. In this regard a crucial test would be the sensitivity of the resistivity to non-linear effects of strong electric fields possibly orienting the incommensurate charge-density-wave (ICDW, stripe) domains thus reducing the boundary mismatches of ordered domains.

Concerning the location of the QCP, we notice that, on the basis of general arguments of the theory of QCP [3], the phase diagram of Fig. 3 in Ref. [1] should be related to the pseudogap behavior for many physical quantities pointed out in Ref. [2]. From this latter analysis the critical point would be located at a doping value $x \approx 0.2$ larger than the value ($x \approx 0.17$) indicated in Fig.3 of Ref. [1]. However, this discrepancy can be solved by noting that the resistivity curve at $x = 0.17$ is likely still affected by superconductivity effects, and the metal-insulator transition at this filling seems to occur at a still finite temperature (of about 15 K). Therefore, the published data of Fig. 1(b) in Ref. [1] are compatible with a shift of the metal-insulator transition at $T = 0$, towards dopings that are larger than the value $x = 0.17$ assigned by the authors, in closer agreement with the analysis of Ref. [2].

An additional observation can be made by contrasting the behavior of LSCO systems with La-doped $Bi_2Sr_2CuO_y$ (Bi-2201) materials [4]. These latter systems are overdoped, making quite natural to locate them on the overdoped (quantum disordered) metallic side of the QCP. Therefore it is not surprising that the low temperature behavior of the planar resistivity is always metallic in Bi-2201. On the other hand they are much more anisotropic than the LSCO systems. Therefore it is again natural to find that ρ_c is always semiconducting in Bi-2201. This strongly twodimensional character also accounts for the robust linear behavior of the resisitivity which is expected in the quantum-critical region above a twodimensional QCP. On the contrary, the transverse hopping, being larger in LSCO, easily becomes coherent by increasing doping, giving rise to threedimensional metallic behavior. In this case the observed $T^{3/2}$ behavior for the planar resistivity in the overdoped regime is explained as the result of the quantum critical behavior in three dimension [5].

The presence of a QCP ruling the physical properties of the superconducting cuprates was repeatedly suggested [6–8,3]. In the proximity of a QCP, critical fluctuations can mediate singular interactions between the quasiparticles, providing both a strong pairing mechanism and a source of normal-state anomalies [6–8]. As far as the nature of this critical point is concerned, the beautiful experiment by Boebinger and coworkers appears as a direct experimental confirmation of the theoretical proposal of the existance of the ICDW-QCP [8,3].

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[1] G. S. Boebinger, *et al.* Phys. Rev. Lett. **77**, 5417 (1996).
[2] B. Batlogg, *et al.*, Physica C **235-240**, 130 (1994).
[3] C. Castellani, C. Di Castro, and M. Grilli, Z. Phys. B, to appear.
[4] Y. Ando, *et al.*, Phys. Rev. Lett. **77**, 2065 (1996).
[5] T. Moriya, *et al.*, Physica C **185-189**, 114 (1991).
[6] P. Monthoux, A.V. Balatsky, and D. Pines, Phys. Rev. B **46**, 14803 (1992).
[7] C. M. Varma, cond-mat 9607105 and references therein.
[8] C. Castellani, C. Di Castro, M. Grilli, Phys. Rev. Lett. **75**, 4650 (1995); A. Perali, C. Castellani, C. Di Castro, and M. Grilli, Phys. Rev. B **54**, 16216 (1996).